English Translation of
PATENT COOPERATION TREATY
PCT
INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Article 36 and Rule 70)

Applicant's or agent's file reference: 6327YT
For further action:
See Notification of Transmittal of International Preliminary Examination Report
(From PCT/IPEA/416)
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Applicant: YOKOHAMA TLO COMPANY, Ltd.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

3. This REPORT is also accompanied by following ANNEXES.
a. x These annexes consist of a total of 17 sheets.
x The Description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

4. This report contains indications relating to the following

items:

I. x Basis of the report

V. x Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

VII. x Certain defects in the international application

Date of submission of the demand: 02 June 2004(02.06.2004)
Date of completion of this report: 29 September 2004(29.09.2004)

International Preliminary Examination Report

International application No.
PCT/JP03/11017

I. Basis of the report

2. This report has been drawn on the basis of the following documents. Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments.

x specification:

- pages 2, 12-14, originally filed,
- pages 1, 3-11, 11/01, 15, submitted to International Preliminary Examining Authority on 02.06.2004

x claims:

- claim Nos. 1, 4, 6, 8, 9, submitted to International Preliminary Examining Authority on 02.06.2004

x drawings:

- Figs. 1-12, originally filed.

3. The amendments have resulted in the cancellation of:

x the claims, Nos. 2, 3, 5, 7, 10, 11

4. (Omitted)

V. Reasoned statement under Article 35 (2) with respect to novelty, inventive step or industrial applicability; citations and explanations supporting such statement:

1. STATEMENT:

Novelty (N)	Claims 1, 4, 6, 8, 9	YES
Inventive step (IS)	Claims 1, 4, 6, 8, 9	YES
Industrial Applicability(IA)	Claims 1, 4, 6, 8, 9	

YES

2. CITATIONS AND EXPLANATIONS (PCT Rule 70.7):

Document 1: JP, 5-347599 A (Matsushita Electric Industrial Co., Ltd.) 1993.12.27

Document 2: JP, 7-95129, A (Fujitu Ltd.) 1995.04.07

The inventions recited in claims 1, 4, 6, 8, 9 are not disclosed in any of he documents cited in the International search report, and they contain novelty and inventive step.

VII. Certain defects in international application

"the CMDA method" in the 18th line and the 21st line in page 1 of the specification seems to be acknowledged as "the CDMA method".

AMENDMENT

(Amendment under Article 11 of the Law)

September 1, 2004

To: Examiner of the Patent Office

1. International Application No. : PCT/JP03/11017

2. Applicant:
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4. Object of Amendment:
   Claim

5. Contents of Amendment
   (1) Claim 2 is deleted.

6. List of Attached Documents
   (1) Page 16 of claim

CLAIMS

1. A communication method comprising the steps of:

producing a plurality of transmission data sequences

$S_{A,X}=(x_0A, 0\ldots0, x_1A, 0\ldots0, x_2A, 0\ldots0, \ldots, x_{m-1}A, 0\ldots0)$

$S_{B,Y}=(y_0B, 0\ldots0, y_1B, 0\ldots0, y_2B, 0\ldots0, \ldots, y_{m-1}B, 0\ldots0)$

…

(0 indicates a null time of a unit length where no signal is generated)

using a plurality of data sequences

$A=(a_0a_1\ldots a_{N-1})$, $B=(b_0b_1\ldots b_{N-1})$, … and

a plurality of coefficient sequences

$X=(x_0x_1\ldots x_{m-1})$, $Y=(y_0y_1\ldots y_{m-1})$, …; and

transmitting said plurality of transmission data sequences $S_{A,X}$, $S_{B,Y}$,… onto the same transmission line at the same time.

2. (Deleted)

3.

AMENDMENT

(Amendment under Article 11 of the Law)

June 2, 2004

To: Examiner of the Patent Office

1. International Application No. : PCT/JP03/11017

2. Applicant:

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4. Object of Amendment:

Specification and Claim

5. Contents of Amendment

(1) "TRANSMISSION SIGNAL PRODUCTION METHOD, COMMUNICATION METHOD, AND DATA STRUCTURE OF TRANSMISSION SIGNAL" in the 3rd line in page 1 of the specification is amended to "COMMUNICATION METHOD".

(2) "a transmission signal production method, a communication method using the transmission signal, and a data structure of the transmission signal" in the 6th line in page 1 of the specification is amended to "a communication method".

(3) "A transmission signal production method according to the present invention ..... is used as a transmission signal." from the 16th line to 19th line in page 3 of the specification is amended to "A communication method according to the present invention ..... onto the same transmission line at the same time."

(4) "transmission data" in the 20th, 21st, 22nd, and 26th lines in page 3 of the specification is amended to "data sequence".

(5) "the transmission data is multiplied ..... are arranged alternately." in the 23rd and 24th lines in page 3 of the specification is amended to "the data sequence is multiplied ..... is placed between data sequences."

(6) "a predetermined number of ..... between neighboring transmission data." in the 1st line in page 4 of the specification is amended to "a null time of ..... between data sequences."

(7) "transmission data" in the 2nd, 13th, and 16th lines in page 4 of the specification is amended to "data sequence".

(8) "a predetermined number of 0 data are added to ..... to produce the transmission data sequence" from the 2nd line to 5th line in page 4 of the specification is amended to "a null time of a predetermined length is added to the end of the data sequence, the data sequence to which the null time is added is multiplied by the coefficients of the predetermined coefficient sequence to produce the plurality

of data sequences, and the plurality of data sequences are arranged in order of coefficients of the coefficient sequence to produce the transmission data sequence".

(9) "the transmission data is .....to produce the transmission data sequence." from the 6th line to the 9th line in page 4 of the specification is amended to "the data sequence is multiplied by the coefficients of the predetermined coefficient sequence to produce the plurality of data sequences, a null time of a predetermined length is added to the end of each data sequence, produced by multiplying the data sequence by the coefficients, and the data sequences, to which the null time of a predetermined length is added, are arranged in order of coefficients of the coefficient sequence to produce the transmission data sequence."

(10) "transmitting the transmission data sequence .....for producing the transmission data sequence." from the 22nd line to the 24th line in page 4 of the specification is amended to "producing a plurality of transmission data sequences for a plurality of data sequences using coefficient sequences different for each data sequence; transmitting the plurality of transmission data sequences; receiving the transmitted transmission data sequences as a reception signal; and restoring the plurality of transmission data sequences by passing the reception signal through matched filters corresponding to said coefficient sequences."

(11) The 13th line to the 16th line in page 5 of the specification are deleted.

(12) "transmission data" in the 21st and 22nd lines in page 5 of the specification is amended to "data sequence".

(13) "A transmission signal production, a communication method, and the data structure of a transmission signal"

in the 10th line in page 6 of the specification is amended to "A communication method".

(14) "a transmission signal production method of the present invention and the data structure of a transmission signal of the present invention" in the 12th line in page 6 of the specification is amended to "a transmission data sequence".

(15) "transmission data" in the 14th, 18th, 19th, 21st, and 24-25th line in page 6 of the specification is amended to "data sequence".

(16) "transmission data" in the 2nd, 3rd, 7th, 8th, 11-12th, 13th, 14th, and 17th lines in page 7 of the specification is amended to "data sequence".

(17) "a predetermined number of 0 data" in the 4th line in page 7 of the specification is amended to "a null time of a predetermined length".

(18) "an interval of time corresponding to" in the 10th line in page 7 of the specification is amended to "an interval of null time corresponding to".

(19) "0 data" in the 14th, 15-16th, and 22nd lines in page 7 of the specification is amended to "null time".

(20) "transmission data" in the 5th, 8th, 9th, 10th, 11th, 14th, 16th, 17th, 19th, 22nd, 23rd, and 24th lines in page 8 of the specification is amended to "data sequence".

(21) "a predetermined number of 0 data" in the 6th line in page 8 of the specification is amended to "a null time of a predetermined length".

(22) "0 data" in the 22nd line in page 8 of the specification is amended to "a null time".

(23) "0 data" in the 1st line in page 9 of the specification is amended to "a null time".

(24) "transmission data" in the 3rd, 10th, and 11th lines

in page 9 of the specification is amended to "data sequence".
(25) "transmission data" in the 3rd line in page 10 of the specification is amended to "data sequences".
(26) "a finite number of data sequences of transmission data" in the 3rd line in page 10 of the specification is amended to "a finite number of data sequences".
(27) "a finite number of transmission data" in the 12th line in page 11 of the specification is amended to "a finite number of data sequences".
(28) "transmission signal production method, ... the data structure of the transmission signal" in the 5th line in page 15 of the specification is amended to "communication method".
(29) "advantageous and are useful for" in the 6th line in page 15 of the specification is amended to "advantageous to and useful for".
(30) "A transmission signal production method ..... a transmission signal." in claim 1 in page 16 of the claim is amended to "A communication method ..... onto the same transmission line at the same time."
(31) "The transmission signal production method ..... between neighboring transmission data." in claim 2 in page 16 of the claim is amended to "A communication method ..... corresponding to said coefficient sequences."
(32) Claim 3 in page 16 of the claim is deleted.
(33) "The transmission signal production method ..... a non-periodic cross-correlation function is 0." in claim 4 in page 16 of the claim is amended to "The communication method ..... non-periodic cross-correlation function is 0."
(34) Claim 5 in page 16 of the claim is deleted.
(35) "The transmission signal production method ..... is

produced from a unitary matrix." in claim 6 in page 16 of the claim is amended to "The communication method ..... formed by a unitary matrix."

(36) Claim 7 in page 17 of the claim is deleted.

(37) "The communication method..... multi-path characteristics of a transmission path." in claim 8 in page 17 of the claim is amended to "The communication method ..... multi-path characteristics of the transmission line."

(38) "finding multi-path characteristics..... to produce the transmission data." in claim 9 in page 17 of the claim is amended to "finding multi-path characteristics ..... using the multi-path characteristics which are found."

(39) Claim 10 in page 17 of the claim is deleted.

(40) Claim 11 in page 17 of the claim is deleted.

6. List of Attached Documents

(1) Page 1 of specification

(2) Pages 3 and 3/1 of specification

(3) Pages 4 and 4/1 of specification

(4) Page 5 of specification

(5) Page 6 of specification

(6) Page 7 of specification

(7) Page 8 of specification

(8) Page 9 of specification

(9) Page 10 of specification

(10) Pages 11 and 11/1 of specification

(11) Page 15 of specification

(12) Pages 16 and 16/1 of claim

(13) Page 17 of claim

==page 1==

SPECIFICATION

COMMUNICATION METHOD

TECHNICAL FIELD

The present invention relates to a communication method, more particularly, is advantageous to a multi-path environment such as that of mobile communication.

BACKGROUND ART

As a demand for data communication is increased in cellular wireless communication and various mobile environments, there is a need for a technology that increases the utilization of wireless frequency resources. For example, in the communication method using the CDMA method, the correlation characteristics of a spreading sequence and the inter-channel interference due to the multi-path characteristics of a transmission path are factors that limit the frequency utilization.

Because the method using Orthogonal Frequency Division Multiplexing (OFDM) is frequency multiplexing using a sine wave, the effect of a multi-path appears as the fading of a signal power and, therefore, there is a problem that it is difficult to separate a transmitted sine wave signal from a multi-path sine wave signal.

On the other hand, the CDMA method can use a pilot signal to separate a transmission signal from a multi-path signal transmitted at the same frequency and at the same time.

The CDMA method is a multiple access method using the spread spectrum communication method. In this spread spectrum communication method, modulation is performed using a spreading code sequence. For example, a periodic sequence with no autocorrelation is used as the spreading code sequence.

For example, as the spreading code sequence that separates the original transmission signal from a multi-path signal,

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increases the power consumption of the amplifier. An increase in the power consumption results in a decrease in the standby time of a mobile terminal.

In view of the foregoing, it is an object of the present invention to solve the conventional problems described above, to reduce an increase in the amplitude of the signal during the modulation of transmission data through spread spectrum, and to reduce the dynamic range of an amplifier on the receiving side.

DISCLOSURE OF THE INVENTION

When transmission data is modulated via spread spectrum, a spreading sequence itself is processed in the prior art to make the periodic spectrum of a transmission signal a non-correlated spectrum. By contrast, when transmission data is modulated via spread spectrum according to the present invention, not the spreading sequence itself is processed as in the prior art but a transmission data sequence is processed to make the periodic spectrum of the transmission signal a non-correlated spectrum. Making the periodic spectrum of the transmission signal a non-correlated spectrum reduces an increase in the amplitude of a signal and reduces the dynamic range of an amplifier on the receiving side.

A communication method according to the present invention comprises the steps of:

producing a plurality of transmission data sequences

$S_{A,X}=(x_0A,\ 0\ldots0,\ x_1A,\ 0\ldots0,\ x_2A,\ 0\ldots0,\ \ldots,\ x_{m-1}A,\ 0\ldots0)$

$S_{B,Y}=(y_0B,\ 0\ldots0,\ y_1B,\ 0\ldots0,\ y_2B,\ 0\ldots0,\ \ldots,\ y_{m-1}B,\ 0\ldots0)$

…

(0 indicates a null time of a unit length where no signal is generated)

using a plurality of data sequences

$A=(a_0a_1\ldots a_{N-1})$, $B=(b_0b_1\ldots b_{N-1})$, … and

a plurality of coefficient sequences

$X=(x_0x_1\ldots x_{m-1})$, $Y=(y_0y_1\ldots y_{m-1})$, …; and

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transmitting said plurality of transmission data sequences $S_{A,X}$, $S_{B,Y}$,... onto the same transmission line at the same time.

The data sequence is digital data including information to be transmitted. On the other hand, the produced transmission data sequence becomes a transmission signal composed by arranging a plurality of data sequences. In the arrangement of the plurality of data sequences, the data sequence is multiplied by the coefficients of the predetermined coefficient sequence, and a null time of a predetermined length is placed between data sequences.

According to a first method for producing the transmission data sequence, the plurality of data sequences, produced by multiplying the transmission sequence by the coefficients, are arranged at intervals by delaying for a time longer than the data length of the data sequence

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and a null time of a predetermined length is arranged between data sequences.

According to a second method for producing the transmission data sequence, a null time of a predetermined length is added to the end of the data sequence, the data sequence to which the null time is added is multiplied by the coefficients of the predetermined coefficient sequence to produce the plurality of data sequences, and the plurality of data sequences are arranged in order of coefficients of the coefficient sequence to produce the transmission data sequence. Alternatively, the data sequence is multiplied by the coefficients of the predetermined coefficient sequence to produce the plurality of data sequences, a null time of a predetermined length is added to the end of each data sequence, produced by multiplying the data sequence by the coefficients, and the data sequences, to which the null time of a predetermined length is added, are arranged in order of coefficients of the coefficient sequence to produce the transmission data sequence.

Another mode of the transmission signal production method according to the present invention is a signal production method wherein a plurality of transmission data sequences are produced using different coefficient sequences and, in an arbitrary combination of two different transmission data sequences, a transmission data sequence is produced so that a finite number of the data sequences included in the transmission data sequence have a range in which a non-periodic cross-correlation function is 0. The non-periodic cross-correlation function is a cross-correlation function between transmission data

sequences having a finite, not infinite, number of transmission data. The periodic spectrum of the transmission signal is made a non-correlation spectrum by producing the transmission data sequence having a finite number of data sequences so that this cross-correlation function has a range in which its value becomes 0.

The coefficient sequence used for the transmission signal production according to the present invention can be selected from a ZCZ sequence, can be a coefficient sequence of an arbitrary vector row selected from a complete complementary sequence, and can be produced using a unitary matrix.

A communication method according to the present invention comprises the steps of producing a plurality of transmission data sequences for a plurality of data sequences using coefficient sequences different for each data sequence; transmitting the plurality of transmission data sequences; receiving the transmitted transmission data sequences as a reception signal; and restoring the plurality of transmission data sequences by passing the reception signal through matched filters corresponding to said coefficient sequences.

In the communication method according to the present invention, the transmission data sequence is used as a pilot signal for measuring

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multi-path characteristics and the multi-path

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characteristics of a transmission line can be obtained by receiving this pilot signal.

In another mode of the communication method according to the present invention, a plurality of transmission data sequences are produced using different coefficient sequences and at least one transmission data sequence selected from the transmission data sequences is used as a pilot signal with other transmission data sequences used as transmission signals. The communication method further comprising the steps of finding multi-path characteristics from the reception signal of the pilot signal; and removing the multi-path characteristics from the reception signal of the transmission signal using the multi-path characteristics, which are found, to produce the transmission data.

Because the periodic spectrum of the pilot signal does not correlate with that of the transmission signal, the signals can be separated by passing them through the corresponding matched filters. The pilot signal is used to obtain the multi-path characteristics from the relation between the transmission signal and the reception signal, and the transmission signal can be obtained from the multi-path characteristics and the reception signal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general diagram showing a transmission signal production method according to the present invention and the data structure of a transmission signal according to the present invention; FIG. 2 is a diagram showing an example of a unitary matrix; FIG. 3 is a diagram showing

an example of a transmission data sequence according to the present invention produced by applying a unitary matrix to a data sequence; FIG. 4 is a diagram showing the relation between data sequences and a transmission data sequence according to the present invention; FIG. 5 is a diagram showing the relation between an input/output signal and a matched filter according to the present invention; FIG. 6 is a diagram showing the status of a data sequence when a signal passes through a matched filter; FIG. 7 is a diagram showing the relation between a pilot signal and transmission signals according to the present invention; FIG. 8 is

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a diagram showing the detection of multi-path characteristics using the pilot signal according to the present invention; FIG. 9 is a diagram showing the communication status of the transmission signal according to the present invention; FIG. 10 is a diagram showing the communication status of the transmission signal according to the present invention; FIG. 11 is a diagram showing an example of the configuration of matched filters applied to the present invention; and FIG. 12 is a diagram showing an example of a signal using a complete complementary sequence as a spreading code sequence.

BEST MODE FOR CARRYING OUT THE INVENTION

A communication method in the best mode for carrying out the present invention will be described below with reference to the drawings. The following describes embodiments of the present invention in detail with reference to the drawings.

FIG. 1 is a general diagram showing a transmission data sequence of the present invention.

According to the present invention, a transmission data sequence (shown in FIG. 1(c)) is produced from a data sequence b (=(b0, b1, b2, b3, …, bN-1)) (shown in FIG. 1(a)) by using a spreading sequence, and this transmission data sequence is used as a transmission signal. N is an arbitrary integer, and the data length of the transmission data is arbitrary N bits.

To produce the transmission data sequence B from the data sequence (b0, b1, b2, b3, …, bN-1) (shown in FIG. 1(a)),

the data sequence (b0, b1, b2, b3, …, bN-1) is multiplied by the coefficients of a coefficient sequence (1, -1, 1, -1) of a predetermined spreading sequence (shown in FIG. 1(b)) to produce a plurality of transmission data sequences B0(=(b0, b1, b2, b3, …, bN-1)), B1(=(-1)·(b0, b1, b2, b3, …, bN-1)), B2(=(b0, b1, b2, b3, …, bN-1)), and B3(=(-1)·(b0, b1, b2, b3, …, bN-1)). The processing, in which the data sequence b (=(b0, b1, b2, b3, …, bN-1)) is multiplied by the coefficients of the coefficient sequence (1, -1, 1, -1) of a predetermined spreading sequence, is

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represented by the Kronecker product as shown in FIG. 1(b).

Next, as shown in FIG. 1(c), the plurality of data sequences, produced by multiplying the data sequence by the coefficients, are arranged at an interval by delaying each data sequence for an interval of the predetermined length of T with a null time of a predetermined length placed between each two data sequences corresponding to the delay time of τ. The predetermined length T is set longer than the transmission data length N, and the data of zeros corresponding to (T-N) bits are arranged. This produces a transmission data sequence such as the one shown in FIG. 1(d). The interval between transmission data is created by delaying from the terminating end of the data sequence to the starting end of the next data sequence for a predetermined time of τ. Arranging the plurality of transmission data as described above creates an interval of null time corresponding to (T-N) bits between each two transmission data pieces.

Instead of delaying the data sequence (b0, b1, b2, b3, …, bN-1), produced by multiplying the transmission data sequence by the coefficients of the predetermined coefficient sequence (1, -1, 1, -1), for a predetermined time, it is also possible to add (T-N) bits of a null time to the end of the data sequence (b0, b1, b2, b3, …, bN-1) to produce a data sequence (b0, b1, b2, b3, …, bN-1, 0, …,0) whose total data length is T bits; to multiply the transmission data, to which the null time is added, by the coefficients of the predetermined coefficient sequence (1, -1, 1, -1) to produce a plurality of data sequences (b0, b1, b2, b3, …, bN-1, 0, …, 0), (-1)·(b0, b1, b2, b3, …, bN-,

0, …, 01), (b0, b1, b2, b3, …, bN-1, 0, …, 0), and (-1)·(b0, b1, b2, b3, …, bN-1, 0, …, 0); and to arrange them in order of the coefficient sequence to produce a transmission data sequence. Adding the (T-N) bits of the null time corresponds to the operation of delaying for the time of τ.

The ZCZ sequence used here is a sequence having a periodic zero correlation zone that has the zero auto-correlation zone characteristics and zero cross-correlation zone characteristics. For example, a complete complementary sequence can be used as the predetermined coefficient sequence. A complete complementary sequence is a sequence

having the auto-correlation characteristics where the sum of the auto-correlation function of the sequences is 0 for all shifts except 0 shift and the cross-correlation characteristics where the sum of the cross-correlation function of the sequences is always 0 for all shifts. For example, a unitary matrix shown in FIG. 2 can be used.

FIG. 3 shows an example of a transmission data sequence produced by multiplying data sequences A0-A3, B0-B3, C0-C3, and D0-D3 by the coefficients of each vector row of the unitary matrix and by adding a null time of a predetermined length.

A plurality of data sequences can be produced by using the original data sequence (1, 0, 0, 0) and by multiplying it by the coefficients of each vector row of the unitary matrix shown in FIG. 2. The data sequences obtained from the first vector row of the unitary matrix are A0=(1, 0, 0, 0), A1=(1, 0, 0, 0), A2=(1, 0, 0, 0), and A3=(1, 0, 0, 0) corresponding to the coefficients. The data sequences obtained from the second vector row of the unitary matrix is B0=(1, 0, 0, 0), B1=(-1, 0, 0, 0), B2=(1, 0, 0, 0), and B3=(-1, 0, 0, 0) corresponding to the coefficients. The data sequences obtained from the third vector row of the unitary matrix is C0=(1, 0, 0, 0), C1=(1, 0, 0, 0), C2=(-1, 0, 0, 0), and C3=(-1, 0, 0, 0) corresponding to the coefficients. The data sequences obtained from the fourth vector row of the unitary matrix is D0=(1, 0, 0, 0), D1=(-1, 0, 0, 0), D2=(-1, 0, 0, 0), and D3=(1, 0, 0, 0) corresponding to the coefficients.

The transmission data sequence is produced by delaying, and adding a null time to, the plurality of data sequences. FIG. 4 shows the relation between the data sequences and

the transmission data sequence using a general expression. When the data sequences A-D are represented by A=(a0, a1, …, aN-1), B=(b0, b1, …, bN-1), C=(c0, c1, …, cN-1), and D=(d0, d1, …, dN-1), the transmission data sequence can

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be produced by adding a null time to them as shown by the determinant in FIG. 4(a).

When the data sequences A-D are represented by A=(a0, a1, …, aN-1, 0, …, 0), B=(b0, b1, …, bN-1, 0, …, 0), C=(c0, c1, …, cN-1, 0, …, 0), and D=(d0, d1, …, dN-1, 0, …, 0), the transmission data sequence can be represented by the determinant in FIG. 4(b).

Next, the communication method according to the present invention that uses a produced transmission signal will be described.

A produced transmission signal can be acquired by a matched filter (matched filter) corresponding to the coefficients of the spreading sequence used for producing the transmission signal. For example, a matched filter, which is a filter that de-spreads the data sequence A and acquires the de-spread data, is formed corresponding to the coefficients of the spreading sequence used for producing the data sequence A.

The relation between an input/output signal and a matched filter is determined based on the complete complementarity of a spreading sequence. FIG. 5 is a diagram showing the relation between an input/output signal and a matched filter.

For example, when the signal A is passed through the matched filter for the signal A in FIG. 5(a), an impulse-like signal can be acquired due to the auto-correlation characteristics. However, when the signal A is passed through a matched filter other than the matched filter for the signal A (matched filter for the signal B to matched filter for the signal D), the signal cannot be acquired due

to the cross-correlation characteristics.

When the signal B is passed through the matched filter for the signal B in FIG. 5(b), an impulse-like signal can be acquired due to the auto-correlation characteristics. However, when the signal B is passed through a matched filter other than the matched filter for the signal B (matched filter for the signal A, matched filter for the signal C, matched filter for signal D), the signal cannot be acquired due to the cross-correlation characteristics.

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Next, the following describes that the transmission signal production according to the present invention can suppress an increase in the amplitude of a transmission signal.

According to the transmission signal production of the present invention, a plurality of data sequences, produced by multiplying them by the coefficients of the ZCZ sequence, are arranged with a delay between each two of them to allow a finite number of data sequences to have a periodic zero correlation zone for producing an impulse-like signal.

Referring to FIG. 6, the status of a data sequence when the signal is passed through a matched filter will be described.

FIG. 6(a) shows the status of a data sequence when the signal A is passed through the matched filter for the signal A.

The transmission signal according to the present invention can be represented as follows by applying a delay time to the ZCZ sequence based on a complete complementary sequence.

$$aA = a(A0)0 + a(A1)T + a(A2)2T + a(A3)3T$$

where $(\cdot)T$ is the time delay of a T time slot (T chip) and the signal length of aA is 4T.

The data signal A shown in FIG. 3 corresponds to a case in which the signal of (AN) is (1, 0, 0, 0) and T=9 in the expression described above.

The signal produced by passing this signal A through the matched filter for the signal A can be calculated by the convolution between the signal A and the matched filter A as follows.

aA*Af = 4a(x, x, …, x, x, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, x, x, …, x, x)

Note that Af corresponds to the matched filter.

The signal produced by the above expression is an impulse-like signal, and the increase in the amplitude can be suppressed.

On the other hand, FIG. 6(b) shows the status of a data sequence when the signal B is passed through the matched filter for the signal A.

The transmission signal B is represented as follows.

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$$aB = a(B0)0 - a(B1)T - a(B2)2T + a(B3)3T$$

The data signal B shown in FIG. 3 corresponds to a case in which the signal of (BN) is (1, 0, 0, 0) and T=9 in the expression described above.

The signal produced by passing this signal B through the matched filter for the signal A can be calculated by the convolution between the signal B and the matched filter A, and the signal produced by passing the signal B through the matched filter for the signal A is as follows.

aB*Af = a (0, 0, …, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, …, 0, 0)

Note that, in the above two expressions, a represents the signal amplitude at the transmission time.

This indicates that, in the transmission data sequence produced according to the present invention, a finite number of data sequences have a range in which the non-periodic cross correlation function is 0 (a range in which continuous 0s are delimited by (-1) in FIG. 6(b) and in aB*Af described above) in an arbitrary combination of a plurality of transmission data sequences. The non-periodic cross correlation function is a periodic cross correlation function when the length is infinite.

In the communication method according to the present invention, at least one of produced transmission signals can be used as a pilot signal to detect the multi-path characteristics of a multi-path transmission line via which the signal is transmitted and to detect the transmission signal from which the multi-path characteristics are removed. FIG. 7 is a diagram showing the relation between a pilot signal and a transmission signal.

For example, assume that the signal A is a pilot signal in FIG. 7. When this signal is transmitted via the multi-path transmission line P and then passed through the matched filter A for the signal A to produce the output signal p, the multi-path characteristics P of the multi-path transmission line can be obtained from this output signal p.

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When the signal B - signal D are transmission signals and are transmitted via the same multi-

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This makes the periodic spectrum of the transmission signal a non-correlated spectrum and reduces the increase in the amplitude of the signals.

The reduction in the increase in the amplitude of the signal also reduces the dynamic range of the amplifier on the receiving side.

INDUSTRIAL APPLICABILITY

The communication method according to the present invention is advantageous to and useful for the multi-path environment of mobile communication.

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CLAIMS

1. (Amended)

A communication method comprising the steps of:

producing a plurality of transmission data sequences

$S_{A,X}=(x_0A, 0\ldots0, x_1A, 0\ldots0, x_2A, 0\ldots0, \ldots, x_{m-1}A, 0\ldots0)$

$S_{B,Y}=(y_0B, 0\ldots0, y_1B, 0\ldots0, y_2B, 0\ldots0, \ldots, y_{m-1}B, 0\ldots0)$

…

(0 indicates a null time of a unit length where no signal is generated)

using a plurality of data sequences

$A=(a_0a_1\ldots a_{N-1})$, $B=(b_0b_1\ldots b_{N-1})$, … and

a plurality of coefficient sequences

$X=(x_0x_1\ldots x_{m-1})$, $Y=(y_0y_1\ldots y_{m-1})$, …; and

transmitting said plurality of transmission data sequences $S_{A,X}$, $S_{B,Y}$,… onto the same transmission line at the same time.

2. (Amended)

A communication method comprising the steps of:

producing a plurality of transmission data sequences for a plurality of data sequences using coefficient sequences different for each data sequence;

transmitting said plurality of transmission data sequences;

receiving said transmitted transmission data sequences as a reception signal; and

restoring said plurality of data sequences by passing said reception signal through matched filters corresponding to said coefficient sequences.

3. (Deleted)

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4. (Amended) The communication method according to claim 1 or 2 wherein, in an arbitrary combination of said plurality of transmission data sequences, a finite number of transmission data sequences in the transmission data sequences have a range in which a non-periodic cross-correlation function is 0.

5. (Deleted)

6. (Amended) The communication method according to one of claims 1, 2, and 4 wherein said coefficient sequences are each formed by a unitary matrix.

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7. (Deleted)

8. (Amended) The communication method according to one of claims 1, 2, 4, and 6 wherein at least one transmission data sequence selected from said transmission data sequences is used as a pilot signal for measuring multi-path characteristics, and

said pilot signal included in the transmission data sequences received via a transmission line has the multi-path characteristics of the transmission line.

9. (Amended) The communication method according to one of claims 1, 2, 4, and 6 wherein a plurality of transmission data sequences are produced using different coefficient sequences and

at least one transmission data sequence selected from said transmission data sequences is used as a pilot signal with other transmission data sequences used as transmission signals, further comprising the steps of:

finding multi-path characteristics from the reception signal of the pilot signal included in the transmission data sequences received via a transmission line; and

producing the transmission data sequences obtained by removing the multi-path characteristics from the reception signal using the multi-path characteristics which are found.

10. (Deleted)

11. (Deleted)